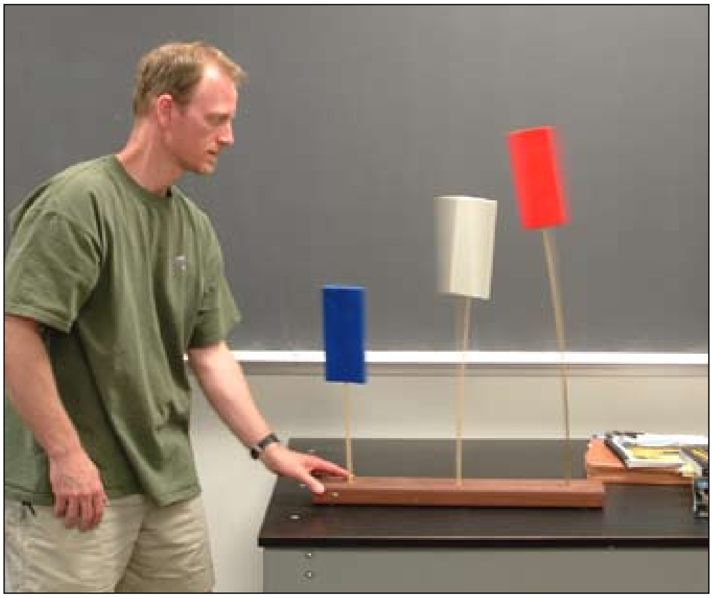
Activity— BOSS Model

Modeling the effect of resonance during an earthquake

Why do some buildings stand and smaller ones fall if they are architecturally equal?



Building Oscillation Seismic Simulation, or BOSS, is an opportunity for students to explore the phenomenon of resonance while performing a scientific experiment that employs mathematical skills. The students are intrigued by a discrepant event involving the BOSS Model and are then set to work experimenting with the natural frequencies of structures. They experience how structures behave dynamically during an earthquake.

Use this block & dowel model or select one of two alternative methods that require less preparation. Although it takes time to prepare, it is worth the effort.

Science Standards (NGSS; pg. 287)

- From Molecules to Organisms—Structures and Processes: MS-LS1-8
- Motion and Stability—Forces and Interactions: HS-PS2-1, MS-PS2-2
- Energy: MS-PS3-1, MS-PS3-2, HS-PS3-2, MS-PS3-5
- Waves and Their Applications in Technologies for Information Transfer: MS-PS4-1, HS-PS4-1, MS-PS4-2
- Earth and Human Activity: HS-ESS3-1, MS-ESS3-2

Additional Resources on this DVD & Internet

VIDEOS: The 3 demonstrations on page 2 of this activity are available on this DVD in the folder:

3. VIDEOS_Earthquake & Tsunami

They are also available on the Internet: **http://www.iris.edu/hq/programs/education_and_outreach/videos#N**

ANIMATIONS relevant to the BOSS Model are in the folders:

2. ANIMATIONS_Earthquake & Tsunami > **Structural Design & EQ Damage**

Links to VIDEOS are on the previous page

This is a demonstration of the BOSS model from Seismic Sleuths and is described in the following pages. **DEMO_Resonance_BOSS Model.mov**

The simplest and most spontaneous way to demonstrate the concept of resonance and building height uses spaghetti and small weights (raisins or marshmallows. Video: **DEMO_Resonance_spaghettiNoodles.mov**.

Demonstration of a modified version of the **BOSS-Lite model** that uses manilla folders. Video: **DEMO_Resonance_Manilla.mov**

Building Stability during Earthquakes**

The three highly effective activities address earthquake resonance on buildings.
We offer different styles and levels of the same basic processes using a variety of materials.

Time: 5-30 Minutes

Target: Grade Level: 6-12

Content Objective: Students will predict how a structure will react to vibrations (oscillations) of different frequencies, and describe the phenomenon of resonance.

Introduction

Why do buildings of different heights respond differently in an earthquake? These activities show that how seismic waves travel through the layers of the Earth can effect how a building might wobble. Aside from architectural constraints, i.e., how well built the structure is, the particular resonance of an earthquake can knock down a small building and spare the skyscraper. The resonance is the oscillation (up-and-down or back-and-forth motion) caused by a seismic wave. During an earthquake, buildings oscillate. If the frequency of this oscillation is close to the natural frequency of the building, resonance may cause severe damage. These models allow students to observe the phenomenon of resonance.

Teacher Preparation—Choice of Models

First, decide which oscillation model fits your class time, as well as preparation time. FEMA's Seismic Sleuth BOSS model has much background material. With all models, *practice before using in class!!* The BOSS model, though most time consuming to construct, works best!

1) The spaghetti-and-marshmallow (or raisin) model is the quickest to assemble and is described in the movie, Resonance2_spag.mov

2) The **BossLite model** has the advantage of looking more like buildings; you could even draw windows on them. Because of the different weight of manilla folders, we found we had to experiment with doubling up the files as they were too floppy.

3) The **BOSS model** is the most elegant, and will be a permanent tool for the classroom. But it does take some assembly time and must be stored. The activity is in FEMA's Seismic Sleuths

Second, find out what students already know about the concepts of amplitude, frequency, and resonance. If they are not familiar with these terms, introduce them by building on what students already know from other areas. They may know, for example, that resonance and frequency are used in describing the tone of musical instruments and the quality of sound produced by different recording techniques and players. The phenomenon of resonance also accounts for laser light and for the color of the sky.

Third, review the terms and concepts introduced in this lesson. Explain that seismic waves caused by earthquakes produce oscillations, or vibrations, in materials with many different frequencies. Every object has a natural rate of vibration that scientists call its natural frequency. The natural frequency of a building depends on its physical characteristics, including the design and the building material. Resonance is a buildup of amplitude in a physical system that occurs when the frequency of an applied oscillatory force is close to the natural frequency of the system. In the case of an earthquake, the ground shaking may be at the same frequency as the natural frequency of a building. Each vibration in the ground may come at or dangerously close to the natural frequency of the structure.

Fourth, ask the class to hypothesize what would happen when buildings of two different heights, standing next to each other, resonate from an earthquake. (Remember to practice a lot before demonstrating.)
Students invariably select the tallest building. Wiggle the model so that the shorter building vibrates the greatest. If you have some images of this effect from actual earthquakes, show them now. The 1985 devastating **Mexico City quake** is a tragic example of mid-size buildings falling preferentially.

Fifth, entice students to further investigation by leaving them with the question: "How could you add structural elements to reduce resonance in a building?" Adding sheer structure keeps things from falling. See ***"Build A Better Wall"***.

Materials:

Watch the 3 videos on resonance to determine how elaborate an activity you desire.

Vocabulary:

Amplitude, Frequency, Oscillation, Resonance.

Student Worksheets:

"Swaying Buildings" student work pages follow the description of the activity.

From “Seismic Sleuths” by AGU/FEMA

The BOSS Model:

Building Oscillation Seismic Simulation

RATIONALE

During an earthquake, buildings oscillate. If the frequency of this oscillation is close to the natural frequency of the building, resonance may cause severe damage. The BOSS model allows students to observe the phenomenon of resonance.

FOCUS QUESTIONS

Why do buildings of different heights respond differently in an earthquake?

OBJECTIVES

Students will:

1. Predict how a structure will react to vibrations (oscillations) of different frequencies.
2. Perform an experiment to establish the relationship between the height of a structure and its natural frequency.
3. Describe the phenomenon of resonance.

MATERIALS

for one BOSS Model

- Master 4.3a, BOSS Model Assembly
- 4 pieces of wood, 1 x 4, each 15 cm (6 in.) long
- 1 piece of wood, 2 x 4, for a base, about 45 cm (18 in.) long
- 2 threaded rods, 10 x 24, each 96 cm (36 in.) long
- 2 threaded rods, 10 x 24, each 61 cm (2 ft.) long
- Goggles for eye protection
- Hacksaw or power saw with metal-cutting blade
- Electric drill or hand drill with ¼-in. and ¾-in. wood bore bits
- Hammer
- 8 wing nuts, 10 x 24
- 8 tee nuts, 10 x 24
- 8 washers, #8
- A wide permanent marker in any color that will contrast with the wood
- Poster paints: red, green, blue, black, and white, and 5 brushes

for each small group

- One copy of Master 4.3b, BOSS Worksheet
- Pencils or pens
- Stopwatch
- Meter stick

TEACHING CLUES AND CUES

As noted in lesson 4.2, you may want to have one group of students working with this model while another is working with the model wall.

TEACHING CLUES AND CUES

Since the rods can break with rough handling, you may want to buy one or two extra.

- 8 washers, #8
- A wide permanent marker in any color that will contrast with the wood
- Poster paints: red, green, blue, black, and white, and 5 brushes (*optional*)

for each small group

- One copy of Master 4.3b, BOSS Worksheet
- Pencils or pens
- Stopwatch
- Meter stick

PROCEDURE

Teacher Preparation

Build the BOSS model by following the directions on Master 4.3a. Practice with your model until you've got a feel for each frequency and you can get any of the rod assemblies to resonate. One technique is to use a firm push first, then watch the number you want and wiggle the base very lightly at its natural frequency to get resonance.

A. Introduction

Find out what students already know about the concepts of amplitude, frequency, and resonance. If they are not familiar with these terms, introduce them by building on what students already know from other areas. They may know, for example, that resonance and frequency are used in describing the tone of musical instruments and the quality of sound produced by different recording techniques and players. The phenomenon of resonance also accounts for laser light and for the color of the sky.

B. Lesson Development

1. Direct students' attention to the BOSS model, and explain its name. Ask the students to predict which numbered rod assembly will oscillate the most when you wiggle the base. Have them hold up 1, 2, 3, or 4 fingers to indicate their prediction. (They will probably say number 1 because it is the tallest.)

2. Oscillate the BOSS model so that some rod assembly resonates other than the one most students predicted. This will baffle the students, so let them predict again. Again make the rod resonate for an assembly they did not predict. Finish this demonstration after several tries by making the rod resonate for the assembly most of the students did predict, so that they get it right. Invite discussion.

3. Relate the blocks and rods to buildings of various heights in an earthquake. Ask students if they think buildings would oscillate like this in an earthquake. (They always do, and in some earthquakes the effect is especially pronounced. In the 1985 Mexico City earthquake, the ground shaking resonated with the natural frequencies of 8-to-10-

VOCABULARY

Amplitude: a measurement of the energy of a wave. Amplitude is the displacement of the medium from zero or the height of a wave crest or trough from a zero point. (In this activity it's how far to the side the block moves.)

Frequency: the rate at which a motion repeats, or oscillates. The frequency of a motion is directly related to the energy of oscillation. In this context, frequency is the number of oscillations in an earthquake wave that occur each second. In earthquake engineering, frequency is the rate at which the top of a building sways.

Hertz (Hz): the unit of measurement for frequency, as recorded in cycles per second. When these rates are very large, the prefixes *kilo* or *mega* are used. A kilohertz (kHz) is a frequency of 1,000 cycles per second and a megahertz (MHz) is a frequency of 1,000,000 cycles per second.

Oscillation or vibration: the repeating motion of a wave or a material—one back and forth movement. Earthquakes cause seismic waves that produce oscillations, or vibrations, in materials with many different frequencies. Every object has a natural rate of vibration that scientists call its natural frequency.

The natural frequency of a building depends on its physical characteristics, including the design and the building materials.

Resonance: an increase in the amplitude (in this case, the distance the top of a building moves from its rest position) of a physical system (such as a building) that occurs when the frequency of the applied oscillatory force (such as earthquake shaking) is close to the natural frequency of the system.

cal characteristics, including the design and the building materials. Resonance is a buildup of amplitude in a physical system that occurs when the frequency of an applied oscillatory force is close to the natural frequency of the system. In the case of an earthquake, the ground shaking may be at the same frequency as the natural frequency of a building. Each vibration in the ground may come at or dangerously close to the natural frequency of the structure.

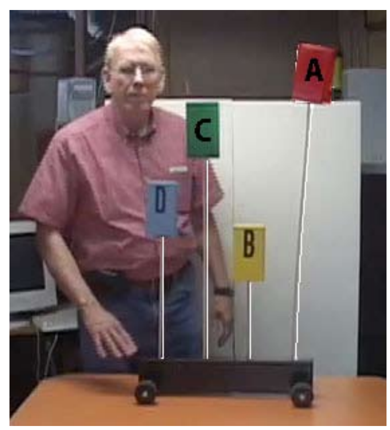
Ask the class to hypothesize what would happen when buildings of two different heights, standing next to each other, resonate from an earthquake. Wiggle the BOSS model so that assemblies 2 and 3 vibrate greatly, and let students see how buildings hammer together during powerful earthquakes. If you have some images of this effect from actual earthquakes, show them now.

Entice students to further investigation by leaving them with the question: "How could you add structural elements to reduce resonance in a building?"

ADAPTATIONS AND EXTENSIONS

1. Tell students that one way to protect a building from resonating with an earthquake is to isolate its foundation, or base, from the ground with devices much like wheels. This technique is called base isolation. Structural engineers are now developing the technology to place buildings on devices that absorb energy, so that ground shaking is not directly transferred to the building.

Invite students to add standard small wheels from a hardware store to their models as an illustration of one of the many base isolation technologies, or add wheels to your own BOSS model, then shake the table. Better yet, place the model in a low box or tray and shake it. Then take out the model, fill the box with marbles or BBs, and replace the model on this base. Now shake the box. Challenge students to come up with other base isolation techniques.



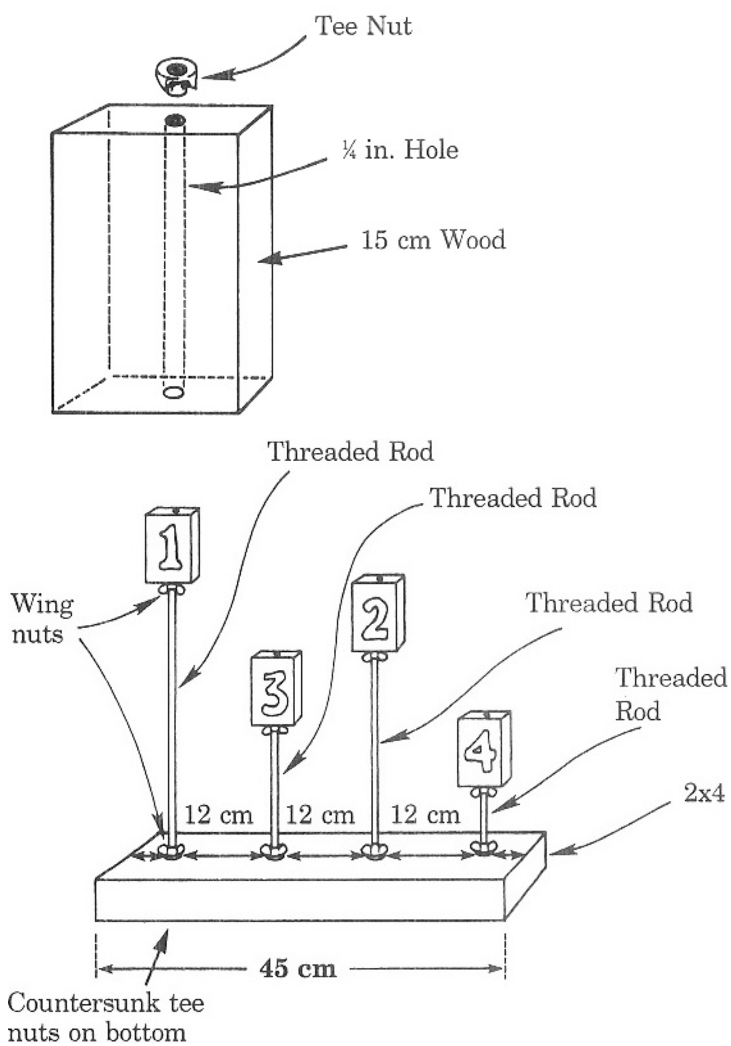
2. If any of your students have studied harmonic motion in a physical science or physics class, challenge them to explain how the BOSS model is an example of an inverted pendulum.

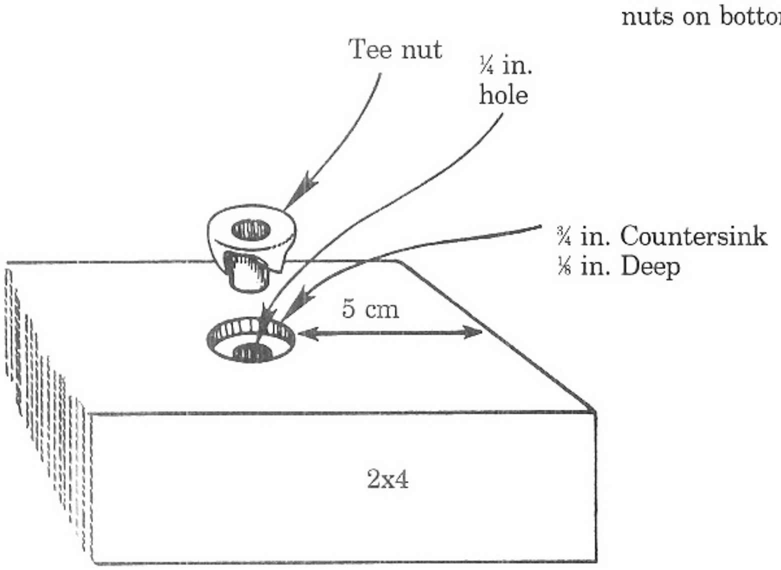
3. To help students connect the numbered rod assemblies to actual buildings, make paper sleeves and decorate them to resemble buildings in your area. At some point in the lesson, slide the sleeves over the rod assemblies to show how buildings can collide, or hammer against each other, during an earthquake. ▲

BOSS Model Assembly

1. Cut one of the meter-long threaded rods down to 75 cm, leaving the other full length.
2. Cut one of the 61-cm threaded rods down to 45 cm, leaving the other full length.
3. Drill a .63-cm (1/4 in.) hole through the center of one of the short sides in each of the 15-cm pieces of wood. (See assembly diagram.)
4. Hammer a tee nut into the hole on one end of each 15-cm piece.
5. Countersink four 3/4-in. holes about 1/8 in. deep into the 45-cm 2 x 4 at 12-cm intervals, as marked on the diagram. (This will allow you to countersink the nuts so they don't scratch the surface where the model rests.)
6. Drill four 1/4-in. holes in the 45-cm 2 x 4 in the countersunk holes.
7. Hammer a tee nut into each countersunk hole. Turn the board over so the tee nuts are on the bottom.
8. Assemble the rods and the base as shown on the diagram.
9. Use the permanent marker to label the 15-cm 1 x 4 blocks in order, 1, 2, 3, and 4.

Optional: Paint the four 15-cm pieces of wood in four different colors. When they are dry, number them, with the white paint.





Teacher notes for Boss Model activity
"Swaying Buildings"

Student Worksheets are on the following pages for the Boss Model activity called Swaying Buildings. These pages have been modified from the AGU/FEMA Seismic Sleuths work book.

Part IV: Relating your findings to earthquake scenarios uses the poster titled "***Violence of Ground Shaking Caused by 3 Types of Earthquakes***" That poster is on this DVD in the folder called:

5. Maps & Posters

> EarthquakeScenarioPoster_SeattleNisqually.pdf

See also the EXTENSION activity in next Activity called:

"***Types of Pacific NW Earthquakes & the BOSS Model***"

Demonstration questions

In this model,

What does the wooden base represent?

What do the standing blocks represent?

What does the shaking back and forth of the model represent?

How is Energy: Moving through this system? (kinetic energy is transferring from your hand to the base of the model and then transferring from the base to the rods and then again transferring from the rods to the blocks causing the blocks to sway back and forth)

For each demonstration ask students to decide--

Which "building" has the greatest amplitude?

As you demonstrate several different frequencies, discuss --

Which "building" resonates at the greatest wavelength?

Which "building" resonates at the least wavelength?

Investigation

Provide students with an experimental question to answer "How does changing the height of the rod affect the natural frequency of the BOSS Model building?"

Have students write a hypothesis before beginning the activity. (If the height of the rod increases then the natural frequency will also increase because ….)

Include a question identifying 2 controlled variables. (the materials the rods are made of, the number of cycles measured, the stopwatch used etc.)

I would place the height of the rod data in the same table with the oscillation data

Students should write a conclusion— (state the question, answer the question, summarize the high and low data and explain how the trend in the data answers the question)

Swaying Buildings: The BOSS Model

Name:

Per: **Date:**

Background Information

Earthquakes generate energy in the form of seismic waves. These seismic waves travel for great distances before finally losing most of their energy. At some time after their generation, these seismic waves will reach the earth's surface, and set it in motion.

When an earthquake causes ground motion beneath a building and when it is strong enough, it sets the building in motion, starting with the building's foundation, and transfers the motion throughout the rest of the building in a very complex way. These motions in turn induce forces that can produce damage. The variety of ways a building responds to earthquake ground motion is the most important cause of earthquake-induced damage to buildings.

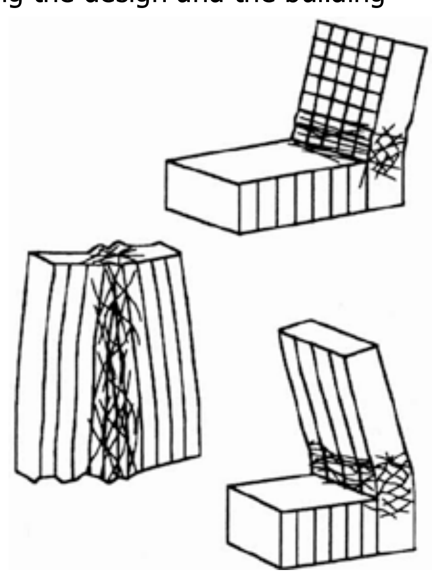
A closer look at ground motion and building response...

The characteristics of earthquake ground motions that have the greatest importance for buildings are the **duration**, **amplitude** (of displacement, velocity and acceleration) and **frequency** of the ground motion.

Seismic waves caused by earthquakes produce **oscillations**, or vibrations, in materials with many different frequencies. Remember, **frequency** is the rate at which a motion repeats, or oscillates. The frequency of a motion is directly related to the energy of oscillation. In this context, frequency is the number of oscillations in an earthquake wave that occur each second. **Another way to look at this is that higher the frequency, the more oscillations or the more vibrations.** In earthquake engineering, frequency is the rate at which the top of a building sways. Frequency is often measured in units called **Hertz (Hz)**. Thus, if two full waves pass in one second, the frequency is 2 hertz (abbreviated as 2 Hz).

Every object has a natural rate of vibration that scientists call its natural frequency. The natural frequency of a building depends on its physical characteristics, including the design and the building materials. How much a building moves or sways during shaking is called its amplitude. **Amplitude** is a measurement of the energy of a wave. Typically amplitude is defined as the displacement of the medium from zero or the height of a wave crest or trough from a zero point so **in this activity it's how far to the side the block moves from the vertical position.**

When studying the effects of earthquakes on buildings, we have to consider another concept. **Resonance** is a buildup of amplitude (in this case, the distance the top of a building moves from its rest position) of a physical system (such as a building) that occurs when the frequency of the applied oscillatory force (such as earthquake shaking) is close to the natural frequency of the system. In the case of an earthquake, the ground shaking may be at the same frequency as the natural frequency of a building. Each vibration in the ground may come at or dangerously close to the natural frequency of the structure.



Buildings have a vibrational frequency depending on their height. If the vibrational frequency resonates with that of the earthquake waves, shaking will be amplified and damage will be more severe, as was the case in the 1985 Mexico City Earthquake. From Bolt (1999).

Using the BOSS model

To develop an understanding of the affect of earthquake waves on buildings, you'll first measure the natural frequencies of the three buildings in the BOSS model.

SAFETY NOTE: Be careful when handling the "buildings" in the BOSS model. Be careful not to break the dowel portions by pulling them too far from their vertical position.

Part I: Determining the natural frequency of different height buildings:

1. Measure the height (cm) of each "building" from the base to the top, and record it.
2. Hold the base stationary, pull the tallest "building" (wooden block) out several centimeters to the side, and release it. Be sure it does not hit the adjoining blocks as it oscillates. As the "building" oscillates, you will use a stopwatch to measure the time for 5 oscillations. Record this number in the correct column below. Practice this until your times for 5 oscillations are fairly close to each other.
3. Practice until you have the same swing each time, then repeat the above measurement three more times. Record your data in the correct column below.
4. Now calculate the **natural frequency** of the building by dividing 5 by the average oscillation time. The frequency is measured in hertz, or cycles per second. Record this frequency in the "natural frequency" column.
5. Repeat this procedure for the other two blocks.
6. Plot the **building height** versus **natural frequency** of each building on the graph provided. You should have 3 data points. Label the graph correctly and include a best-fit line.

Data Table: Building Heights and Oscillation Times

Building	*Building Height (cm)*	*Oscillation Time (s/5 cycles)*				*Avg. Oscillation 5 Times (s/5 cycles)*	*Natural Frequency (Hz =cycles/s)*
		Trial #1	*Trial #2*	*Trial #3*	*Trial #4*		
Tall							
Medium							
Short							

Dependent Variable:

Independent Variable:

Questions *Use complete sentences for full credit.*

1. From your graph, what is the shape of the line produced by plotting "building height" versus "natural frequency"?

2. What relationship do you notice if any, between the height of the "buildings" and their natural frequencies? Support this relationship with specific data from this activity.

3. Predict what would happen when buildings of two different heights, standing next to each other, resonate from an earthquake.

4. Explain how resonance can increase the damage done to buildings during earthquakes.

Part II: Determining Building Period from its Natural Frequency

Another way to understand the behavior of buildings during earthquakes is to think of the building's response in terms of another important quantity, the building's **natural period**. The building period is simply the inverse of the natural frequency: **Whereas the frequency is the number of times per second that the building will vibrate back and forth, the period is the *time* it takes for the building to make one complete vibration.** The relationship between frequency (*f*) and period (T) is thus very simple math:

Period = 1 divided by the **frequency**

or

$$T = 1/f$$

When the frequency of the ground motion during earthquakes is near the building's natural frequency, we say that the building and the ground motion are in resonance with one another. Resonance tends to increase or amplify the building's response. Because of this, buildings suffer the greatest damage from ground motion at a frequency close or equal to their own natural frequency.

The Mexico City earthquake of September 19, 1985 provides a striking illustration of this. A majority of the many buildings which collapsed during this earthquake were around 20 stories tall--i.e., they had a natural period of around 2.0 seconds. These 20 story buildings were in resonance with the frequency of the 1985 earthquake waves. Other buildings, of different heights and with different vibration characteristics, were often found undamaged even though they were located right next to the damaged 20 story buildings.

Procedures for calculating the period

1. Copy the building heights and natural frequencies for each building from the table that you completed in part I.
2. Next, calculate the **natural period** of each building by dividing 1 by the natural frequency. Fill in the table below.
3. Plot the **building height** versus **natural period** of each building on the graph provided. You should have 3 data points. Label the graph correctly and include a best-fit line.

Data Table: Building Heights and Natural Periods

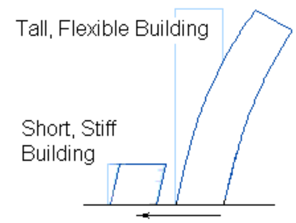
Building	**Building heights (cm)**	**Natural Frequencies *(Hz =cycles/s)***	**Natural period (s)**
Tall			
Medium			
Short			

Building Natural Periods	
Number of stories	*Natural period*
2	0.2
5	0.5
10	1.0
20	2.0
30	3.0
50	5.0

Dependent Variable:

Independent Variable:

Part III Relating ground motion to building motion
Based on your data above, you'll predict and test the effect of different ground motions on the different buildings.



http://earthsci.org/processes/geopro/seismic/seismic.html

The tallest building
Write a one-sentence prediction of which frequency of ground motion (high frequency, short period; or intermediate frequency, intermediate period; or low freq

1. uency, long period) is going to MOST affect the **tall** building.

    Prediction: Tall buildings will be most affected by:

    Testing: Begin gently moving the base of the model back and forth parallel to the long dimension of the model. (Your instructor will demonstrate this for you.) Pay close attention to the frequency of the back and forth motion. Through trial and error, find the frequency of the motion of the base that moves ONLY the **tall** building.

    Findings: The frequency of base motion that most affects the tall building is (circle one):
    a. High frequency, short period waves
    b. Intermediate frequency, intermediate period waves
    c. Low frequency, long period waves

Now that you've figured out a little bit more about how ground motion affects buildings, lets take a closer look at a variety of different height buildings.

The shortest building

2. Write a one-sentence prediction of which frequency of ground motion (high frequency, short period; or intermediate frequency, intermediate period; or low frequency, long period) is going to MOST affect the **short** building.

    Prediction: Short buildings will be most affected by:

    Testing: Begin gently moving the base of the model back and forth parallel to the long dimension of the model. Pay close attention to the frequency of the back and forth motion. Through trial and error, find the frequency of the motion of the base that moves ONLY the **short** building.

    Findings: The frequency of base motion that most affects the short building is (circle one):
    a. High frequency, short period waves
    b. Intermediate frequency, intermediate period waves
    c. Low frequency, long period waves

The intermediate height building

3. Write a one-sentence prediction of which frequency of ground motion is going to MOST affect the **intermediate height** building.

   Prediction: Intermediate height buildings will be most affected by:

   Testing: Begin gently moving the base of the model back and forth parallel to the long dimension of the model. Pay close attention to the frequency of the back and forth motion. Through trial and error, find the frequency of the motion of the base that moves ONLY the **intermediate height** building.

   Findings: Describe in two sentences both the frequency and period of base motion that most affects the intermediate height buildings.

Part IV: Relating your findings to earthquake scenarios

Using your findings above, and the "Violence of Ground Shaking Caused by 3 Types of Earthquakes" poster, answer the following questions.

1. How is the frequency of ground shaking during a shallow earthquake going to be different than the ground shaking during a subduction zone earthquake?

2. Explain why a large, subduction zone earthquake on the Cascadia subduction zone is **unlikely** to cause extensive damage to single-story houses and buildings. (*Hint: look at the ground motion necessary to move the small building in Part III*)

3. How will this duration of shaking likely affect the different height buildings?

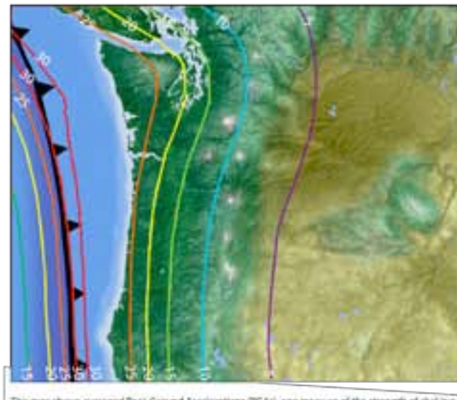
4. Resonance occurs when a structure vibrates at its natural frequency. This may have devastating effects because the displacement (the distance it moves) increases. If an earthquake sends out waves at high frequency, which building would you prefer to be in and why?

5. One way to protect a building from resonating with an earthquake is to isolate its foundation, or base, from the ground with devices much like wheels. This technique is called base isolation. Propose two other methods of base isolation.

6. Suppose you added more weight to the top of each building. How does this change its natural frequency? Would this help prevent damage in an earthquake (assume high frequency)? Try this by attaching weights to the building and determining its new natural frequency.

Violence of Ground Shaking Caused by 3 Types of Earthquakes

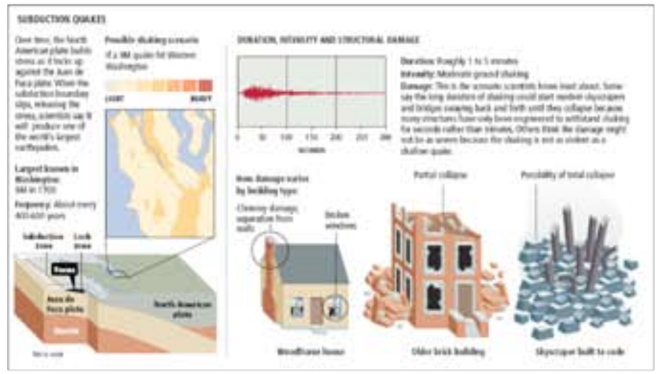
Quake Scenarios: Type of earthquake determines potential extent of damage

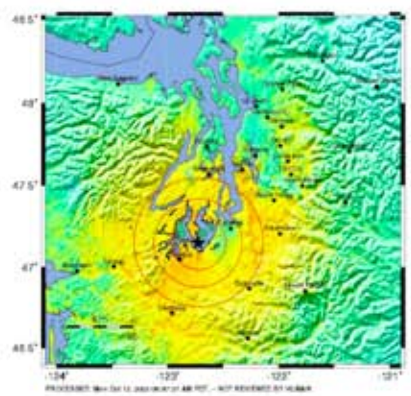


This map shows averaged Peak Ground Accelerations (PGAs), one measure of the strength of shaking. Specific locations may have higher or lower PGAs, and significantly more or less damage. Site conditions such as soil and building type will affect the type and amount of damage at any given place.

1) Magnitude 9.0, Subduction Zone Earthquake

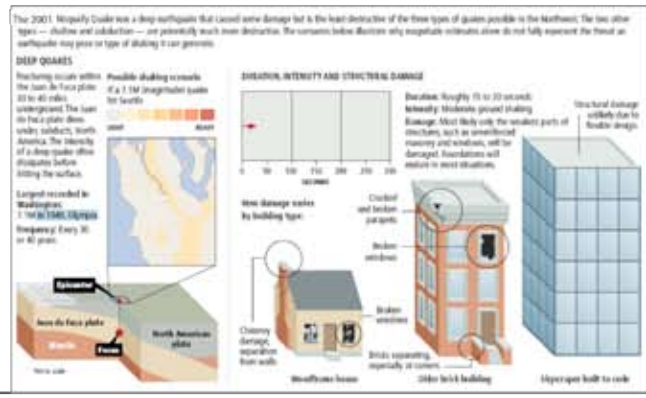
How long would the ground shake?

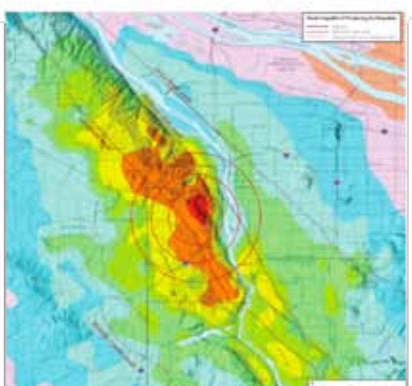




Measured Peak Ground Acceleration (PGA) for the February 28, 2001 Nisqually Earthquake. Magnitude 6.8.

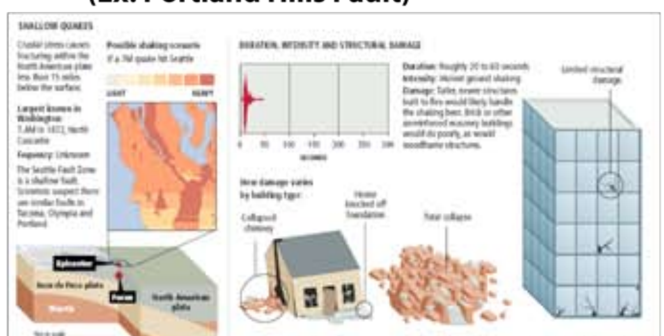
2) Magnitude 7, Deep Earthquake (Ex. Seattle)





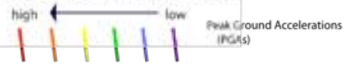
Predicted (not measured) Peak Ground Acceleration (PGA), or intensity of shaking for an earthquake along the Seattle Fault. Planning Scenario only!

3) Magnitude 6.8, Shallow Crustal Earthquake (Ex. Portland Hills Fault)

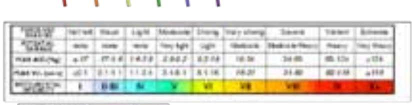


EXPLANATION FOR COLORS ON THE MAPS

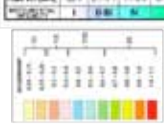
MAP 1



MAP 2



MAP 3

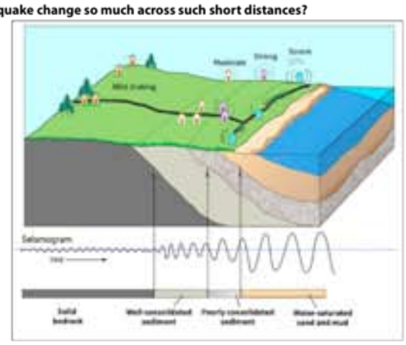


[Maps are from different sources thus have different color schemes]

***What is acceleration?** You are held to the Earth with a force that is equal to your mass times the acceleration of gravity. The number 100 (not shown here) indicates ground shaking that can produce acceleration exceeding the Earth's gravity. This would mean that stones and people can be thrown into the air.

Why does the intensity of an earthquake change so much across such short distances?

How seismic waves shake the ground during an earthquake depends on the geologic layering. The figure below shows how an earthquake wave going through solid bedrock has high frequency and low amplitude. When the waves go through weaker material, they oscillate with higher amplitude but lower frequency. Imagine dropping a rock on concrete and recording the vibration compared to dropping a rock on a trampoline or a mattress.



Poster produced by Jenda Johnson and Robert Butler for Teachers on the Leading Edge. Maps from the Washington State Department of Natural Resources. Graphics for earthquake damage used with permission of artist Julie Simon, Seattle Post Intelligencer.